SWTW 2-0-1-7

SW Test Workshop

Semiconductor Wafer Test Workshop

# New method to measure CCC (Current Carrying Capability) of thin probe wire

Probe Innovation

Probe Innovation USA

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# 1. Outline

## 1.1. General Definition of CCC :

Current in wire at definite temperature difference between wire and atmosphere

## 1.2. Conventional CCC measurement standard

Difficulty in measuring temperature of thin wire.

**Thermocouple :**

Area size is too large for thin wire.
⇒ Error in heat radiation is too large.

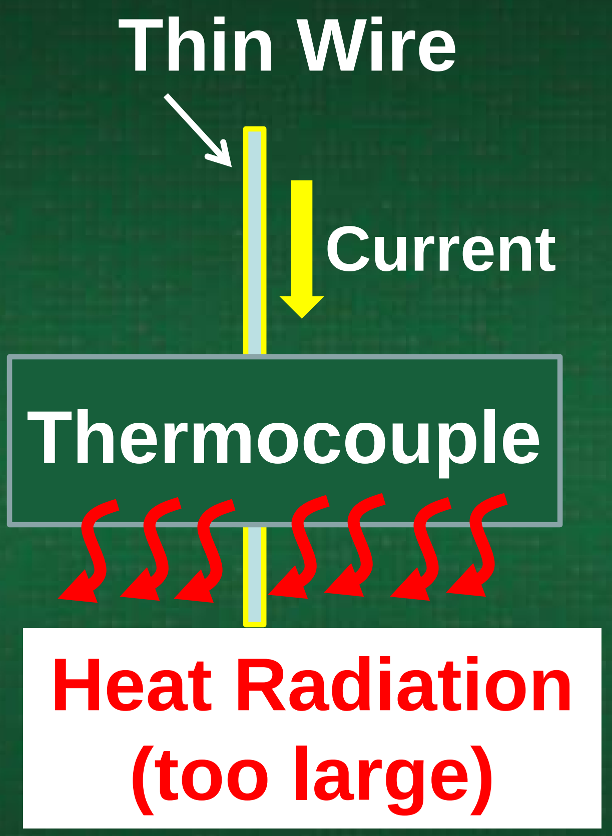



Figure 1-1 Illustration of Heat Radiation from Thermocople

# Table 1-1 CCC evaluation standard（ISMI CCC)

| Electric Current | 1.2 A | 1.25 A | 1.3 A | 1.35 A | Standard |
|---|---|---|---|---|---|
| Force Reduction rate | 0 % | 11 % | 19 % | 27 % | 15 % down |
| Depress | 13 µ | 14 µ | 15 µ | 20 µ | 15 µ |
| CCC | Pass | Pass | Fail | Fail | |

CCC :
Maximum Current before softening due to temperature rise

**Very practical and useful,**
**but no temperature related information**

# 1.3. New method to measure CCC of Thin Wire

## (1) Unique Temperature Measurement

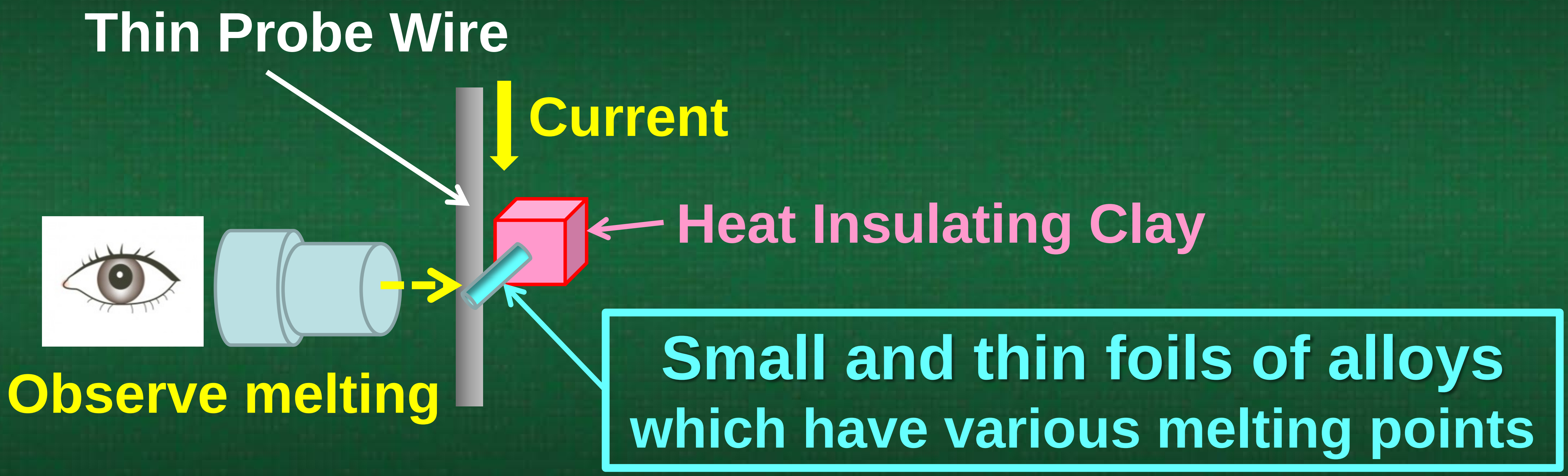
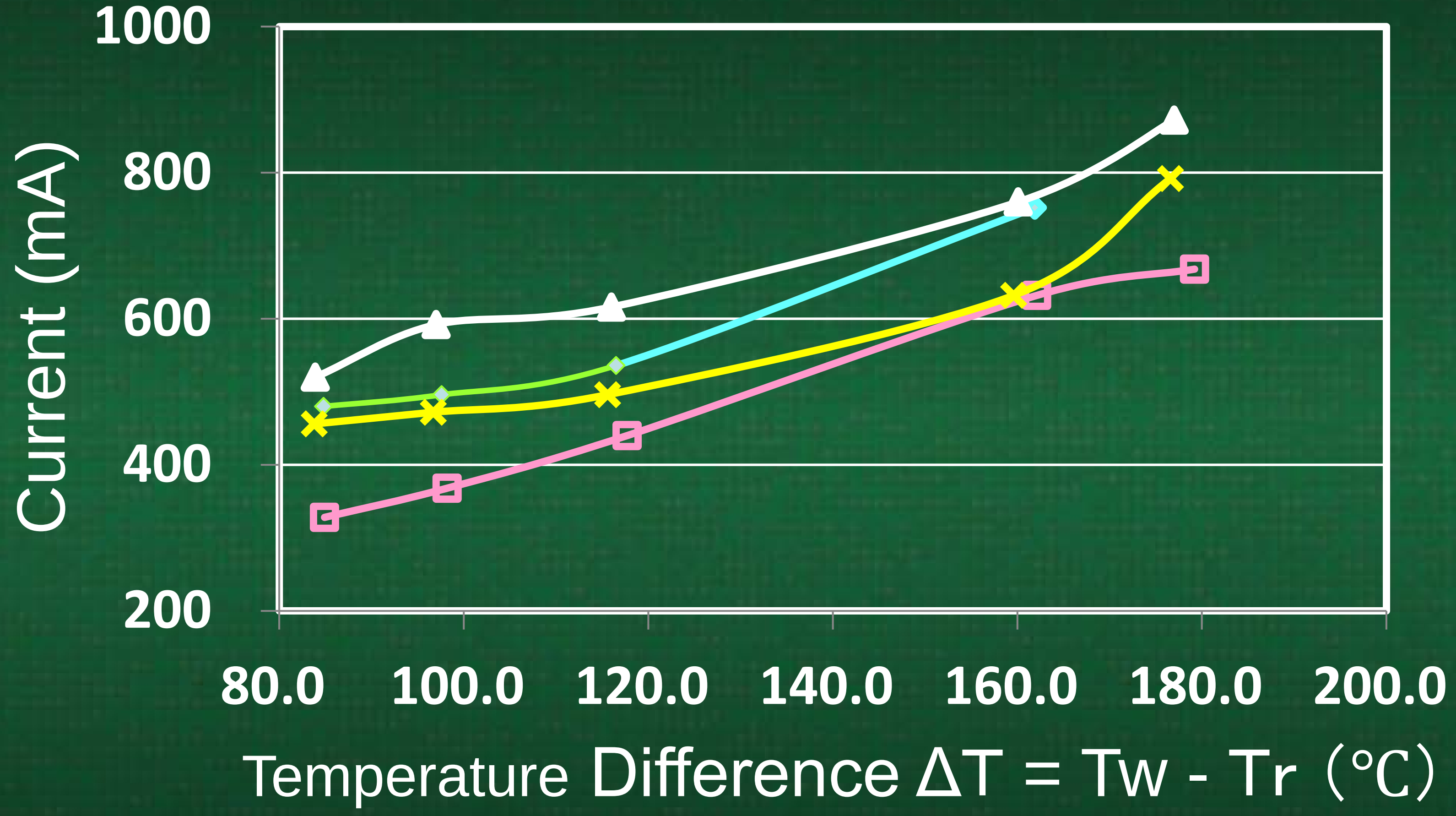



**Figure 1-2 Illustration of New Method to measure Temperature of Thin Wire**

## (2) CCC Basic theory has been verified.

## (3) Sample of Measured CCC order : (Wire Diameter = 63 μ)




1. Rhodeo6
2. Beryllium Copper (BeCu)
3. Rhenium Tungsten (ReW)
4. Paliney H3C

Tw : Wire Temperature

Tr : Room Temperature

**Figure 1-3 Sample of Measured CCC**

# 1.4. New Discoveries through Experiments

Thinking of Solder Capped Cu-Pillar, availability of each probe material was checked. Through additional two tests new discoveries were made.

1) Test for Wet Property to solder
2) Electric Discharge Test

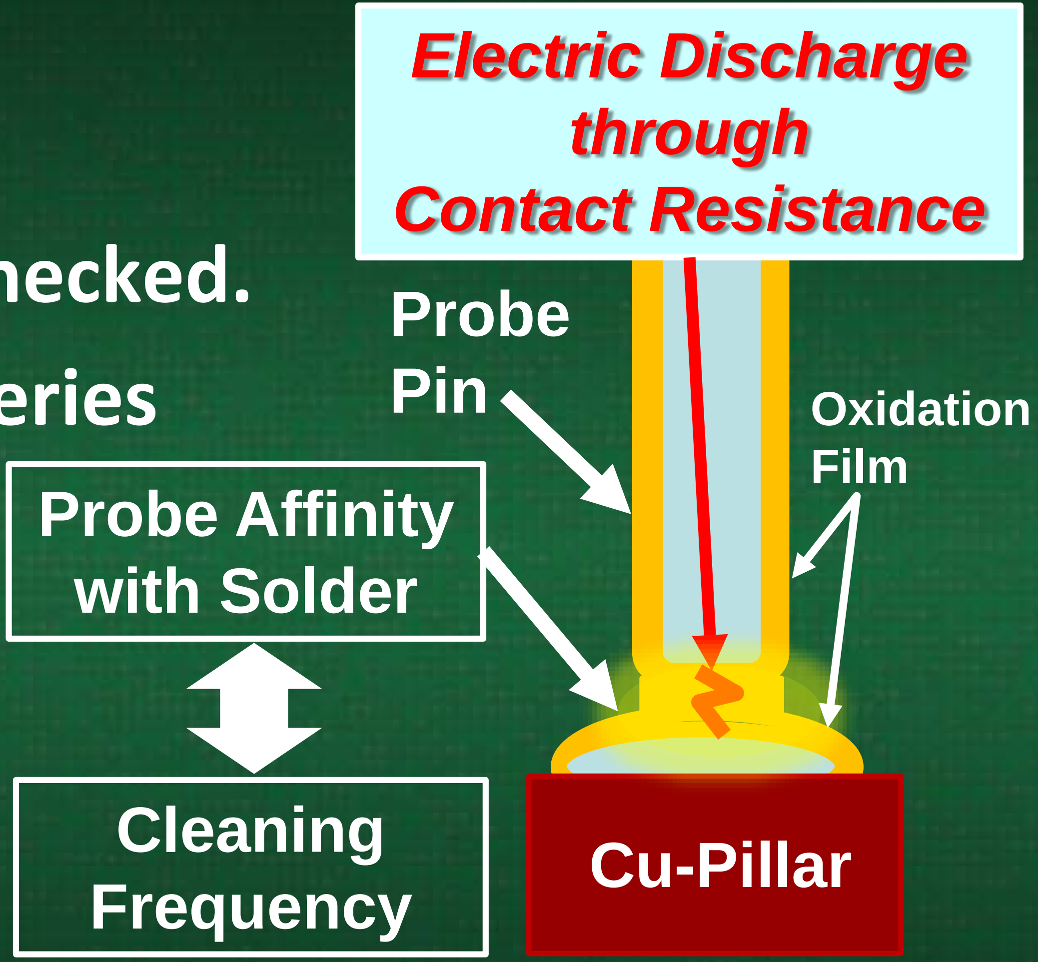



Figure 1-4 Illustration of Solder Capped Cu-Pillar

# 2. Basic Theory of CCC

## 2.1. Heat generation of conductor

H = UL
= L* I^2*R ---(2-1)

## 2.2. Heat radiation of conductor

q = h * S * (Ts - To)
----------(2-2)

## 2.3. Heat Balance

H = q
And set S = L * π * d
Then (2-3) is obtained
In next page.

**Table 2-1 Symbols and contents**

| Symbol | Name | Dimension |
|---|---|---|
| H | Total heat generation | W |
| L | Length of heat radiation object | m |
| U | Heat generation per unit length | W/m |
| I | Current | A |
| R | Resistance per unit length | Ohm/m |
| ρ | Resistivity of conductor material | Ohm・m |
| q | Heat Flow | W |
| h | Heat transfer rate | W/m^2/℃ |
| S | Area of heat radiation object | m^2 |
| d | Diameter of heat radiation object | m |
| A | Area of conductor cross section | m^2 |
| Ts | Surface temperature of object | K |
| To | Neighboring temperature | K |

$$I = \sqrt{h * \pi * d * ( Ts - To ) / R} \text{ ----------- (2-3)}$$

Conductor resistance = R * L = ρ * L/A

Therefore Resistance per unit length

$$R = \rho / A = 4 * \rho / (\pi * d^2) \text{ --------------(2-4)}$$

Substituting equation (2-4) into equation (2-3), equation (2-5) is obtained.

$$I = \sqrt{h * \pi * d * ( Ts - To ) / R}$$

$$= \pi * \sqrt{h * d^3 * (Ts - T0) / (4\rho)} \text{ ------- (2-5)}$$

# 3. New method to measure CCC of thin wire

## (1) CCC Measurement System

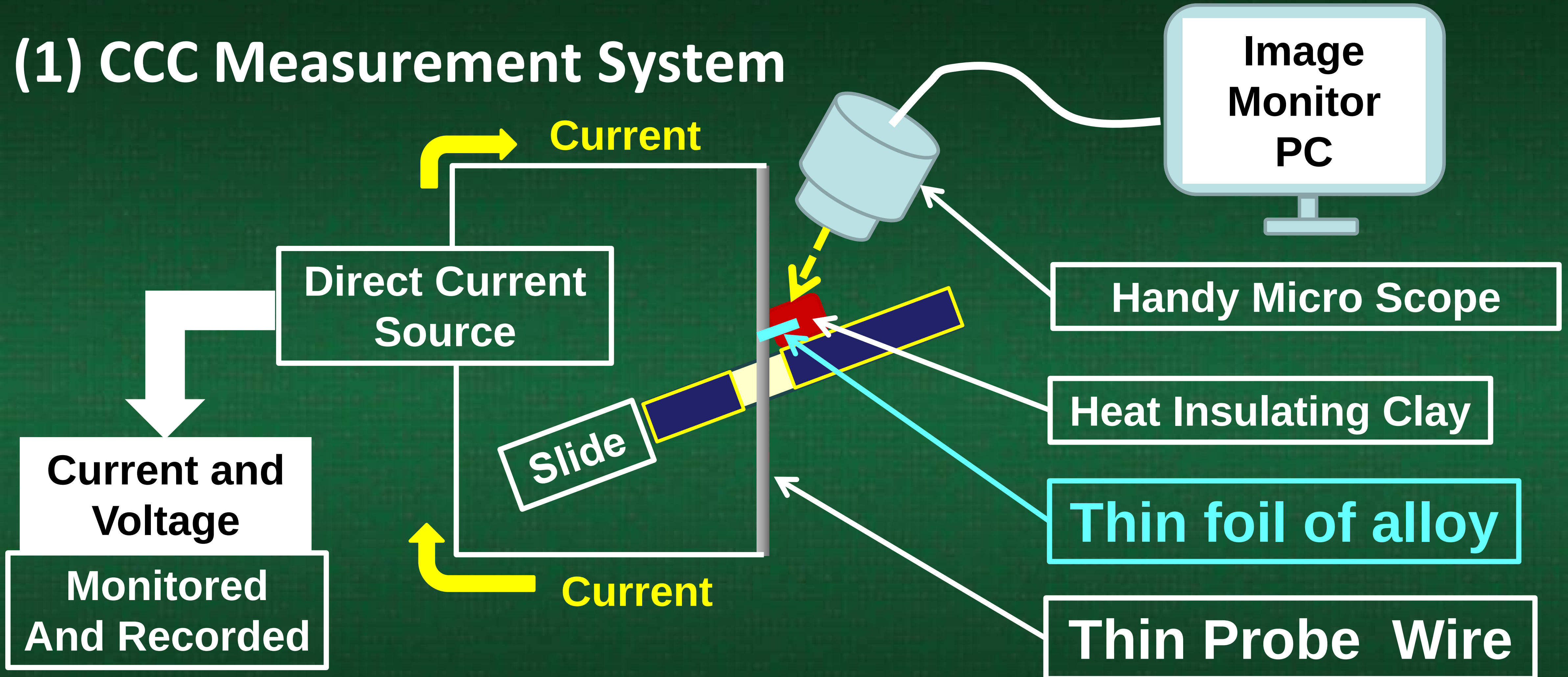
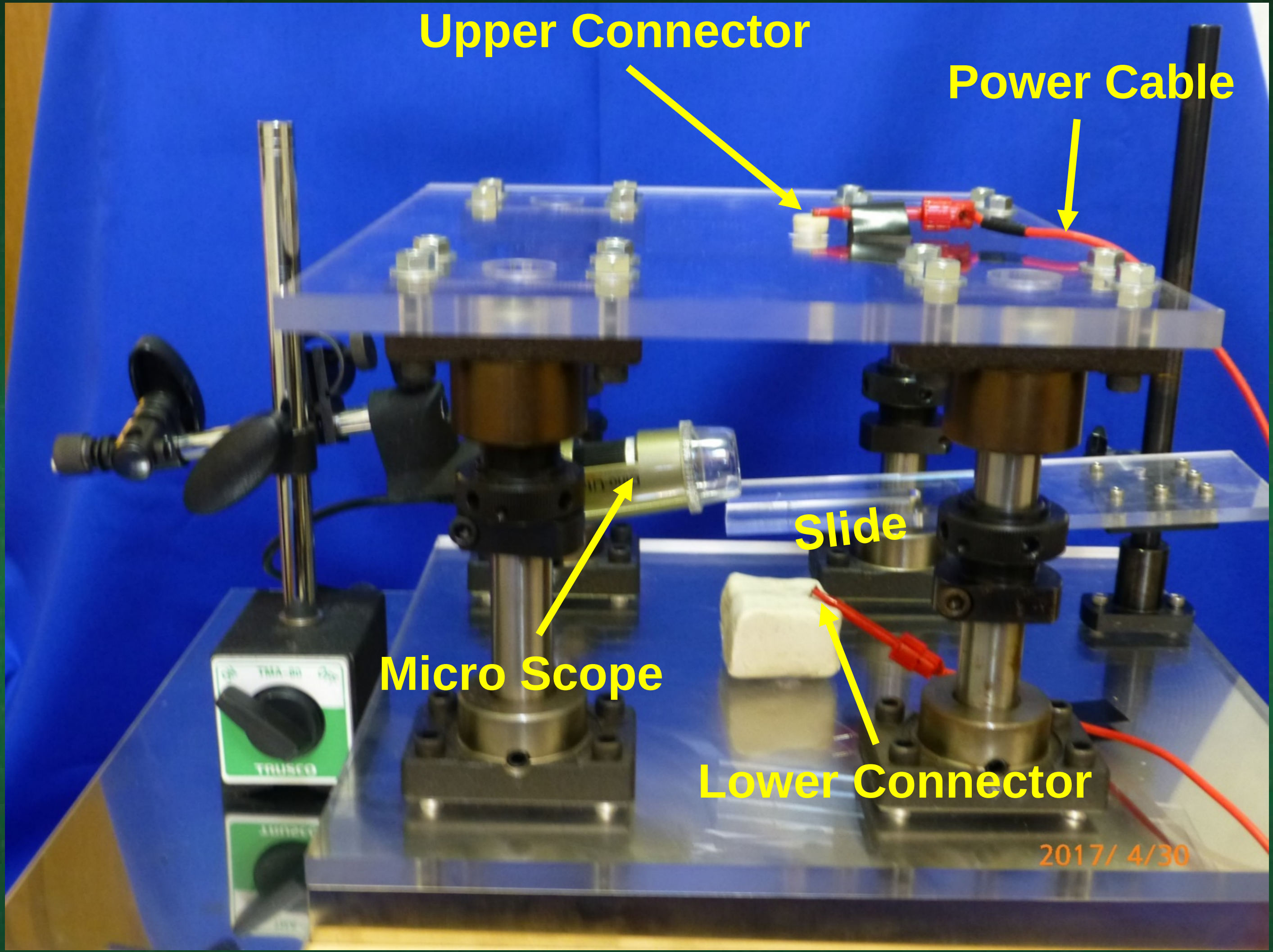
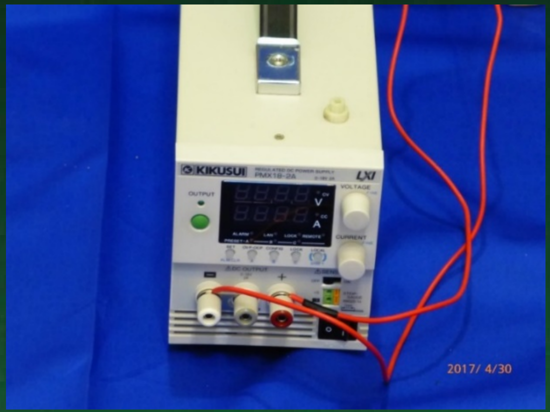


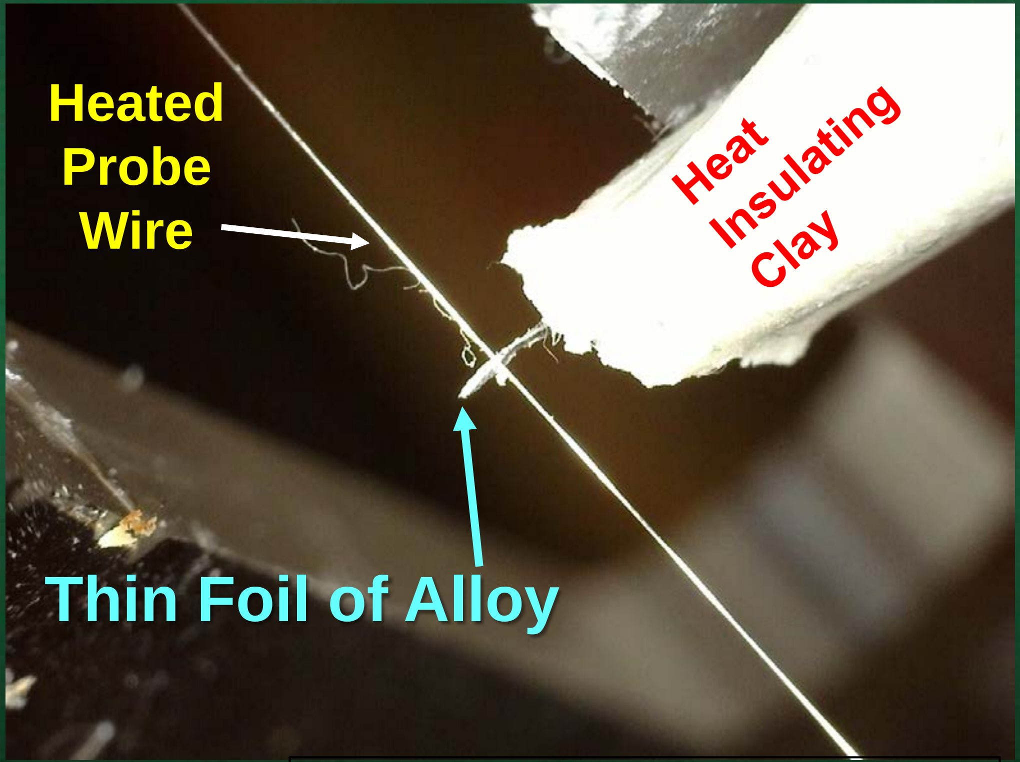

Figure 3-1 CCC of thin wire measurement System




Picture 3-1 Appearance of measurement System




Picture 3-2 DC Power Source (Kikusui PMX 18-2A)




Video 1 Foil Alloy Melting Test

# (2) Materials Applied to the test :

## Wire Materials :

Rhodeo6, Beryllium Copper (BeCu), Rhenium Tungsten (ReW), and Paliney H3C（H3C)

## Wire Diameter :

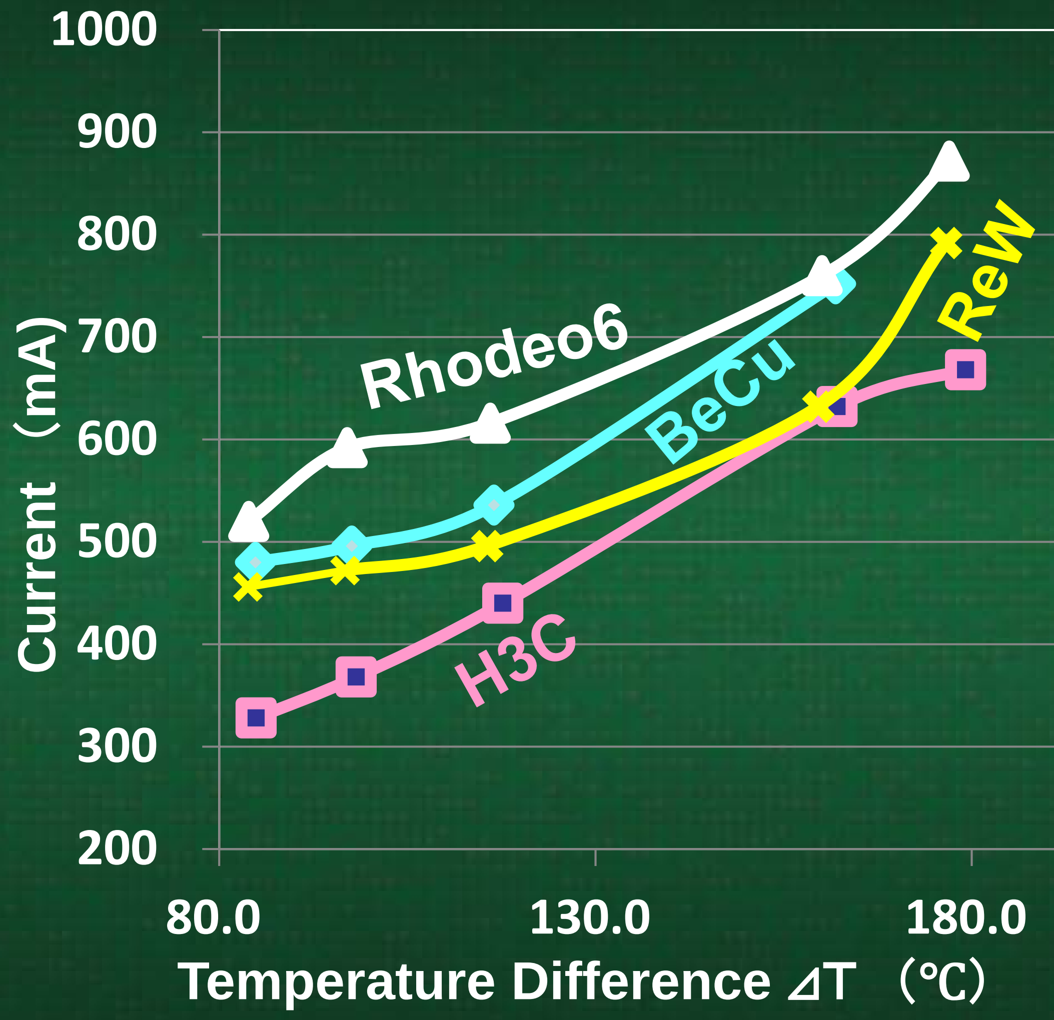
2.5 mils (63 μ）

## Wire Length :

CCC Test : 100 mm and 150 mm
Current Resistance Test : 50 mm

# 4. Results of CCC and Resistance/Current Properties

(a) CCC (2.5 mils, 150 mm)




(b) Resistance/Current (2.5 mils, 50 mm)

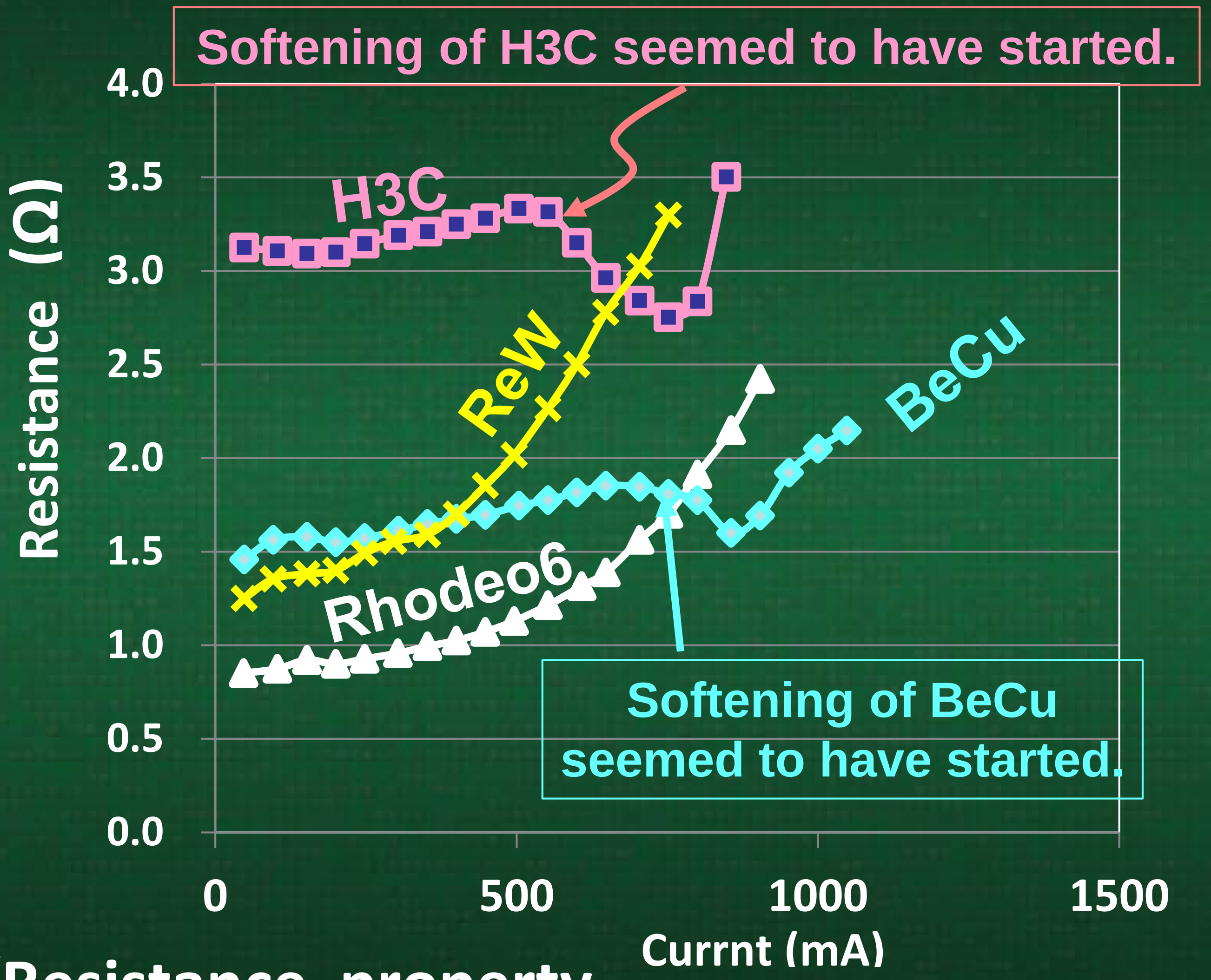



Figure 4-1 CCC and Current/Resistance property

## (c) CCC (Wire = 2.5 mils, Length = 100 mm)

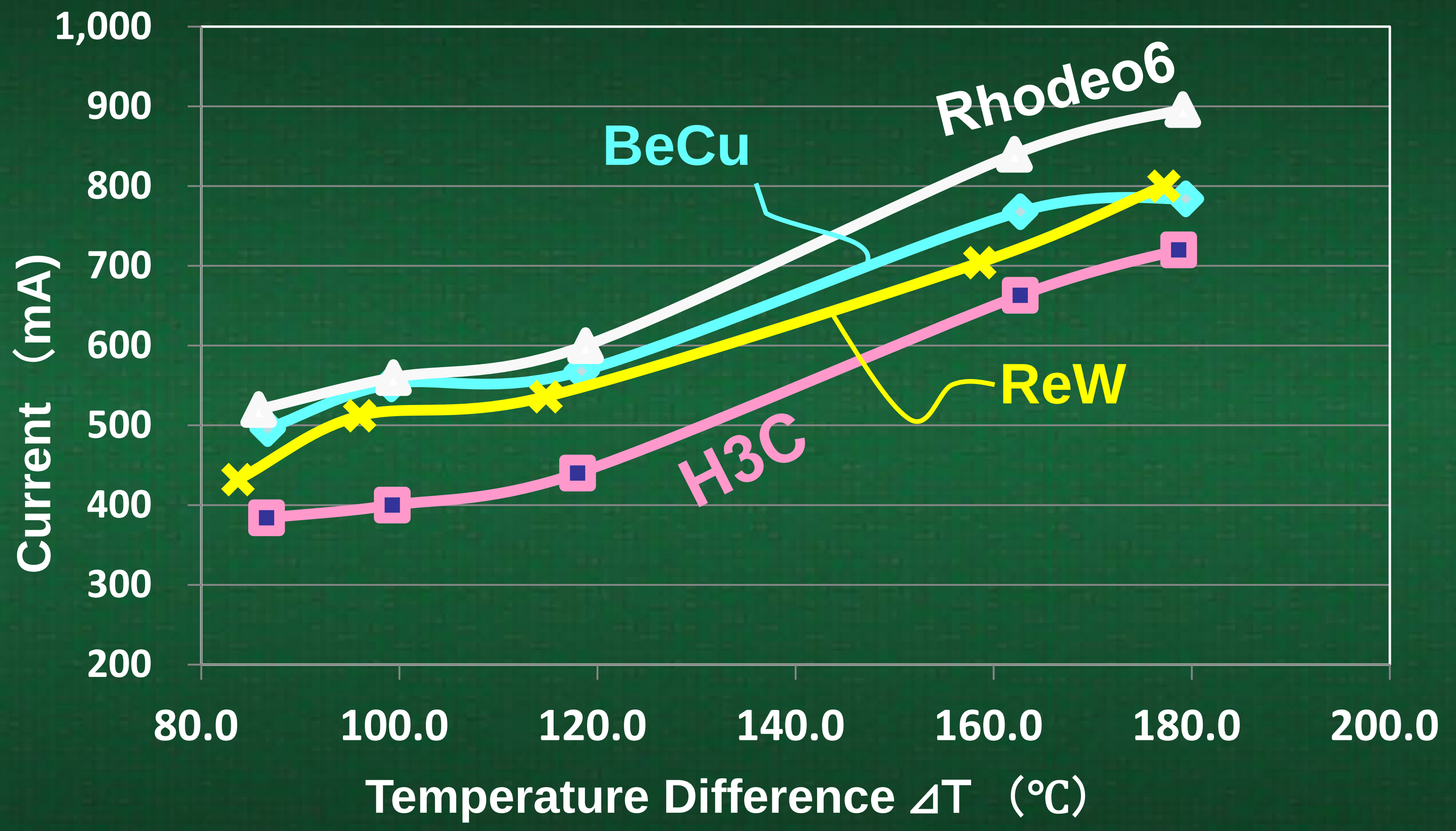
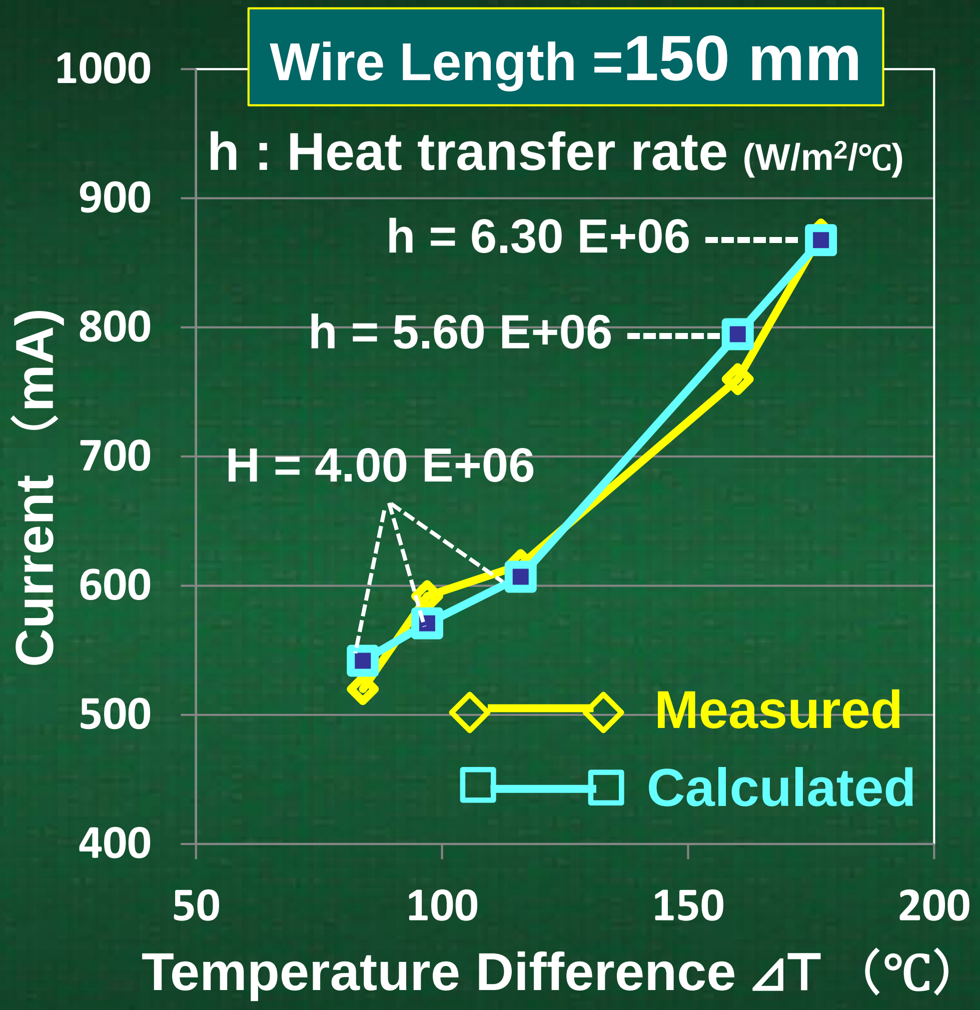



Figure 4-2 CCC (Wire D= 2.5 mils, L= 100 mm)

# 5. Verification of CCC Basic Theory



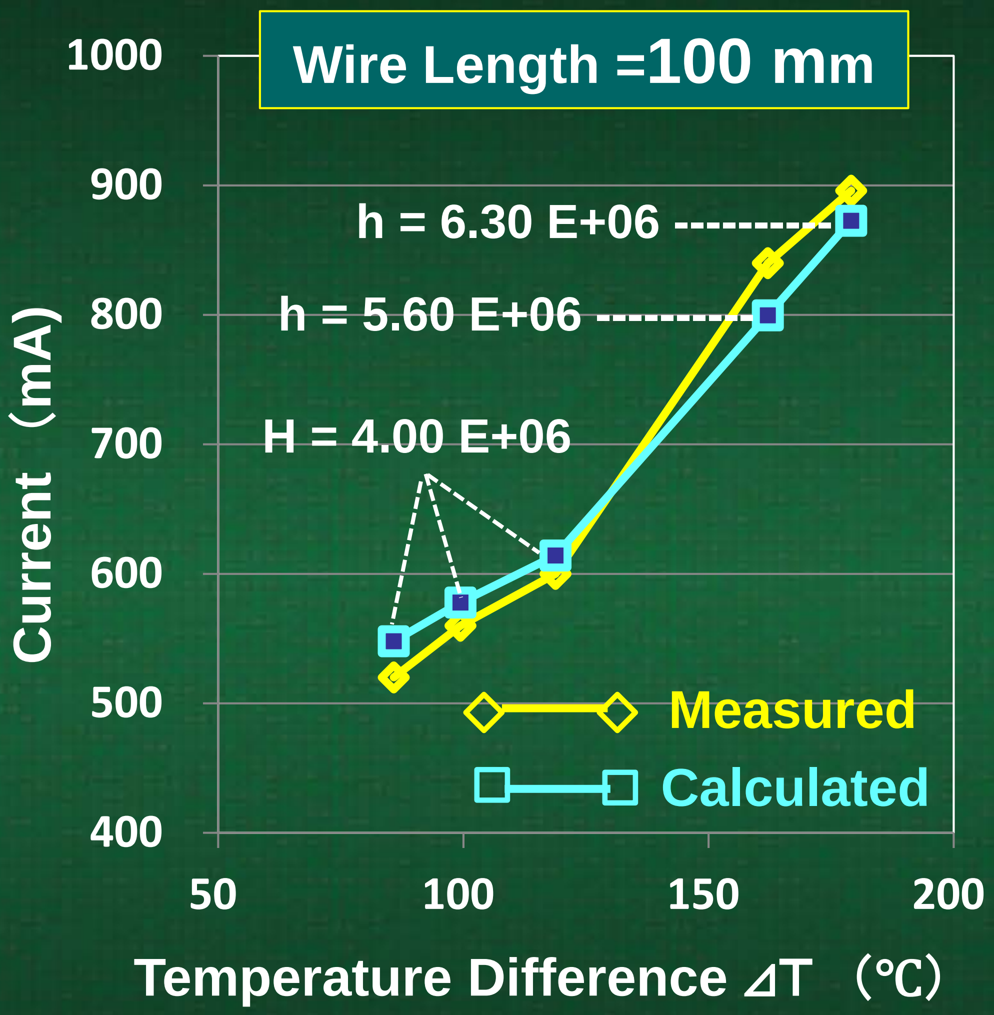




Figure 5-1 Comparison between measured and calculated CCC data

(Material = Rhodeo6, Diameter = 2.5 mils)

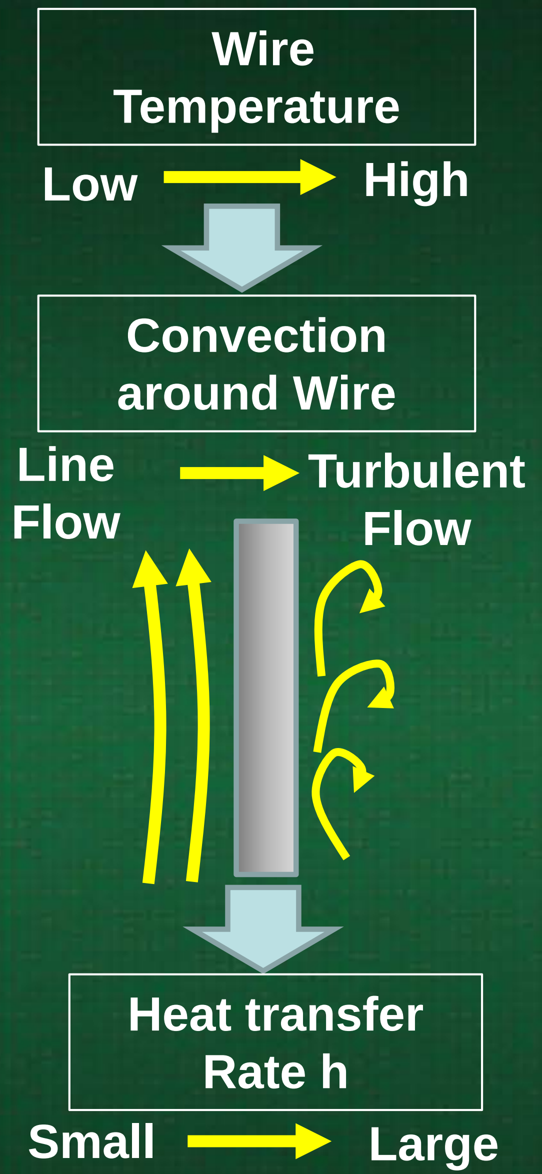



Figure 5-2 Illustration of Heat Transfer Rate Change

# 6. New Discoveries through Experiments

Thinking of Solder Capped Cu-Pillar, availability of each probe material was checked. Through following additional two tests, new discoveries were made.

1) Test for Wet Property to solder related to affinity with solder and cleaning frequency.

2) Electric Discharge Test

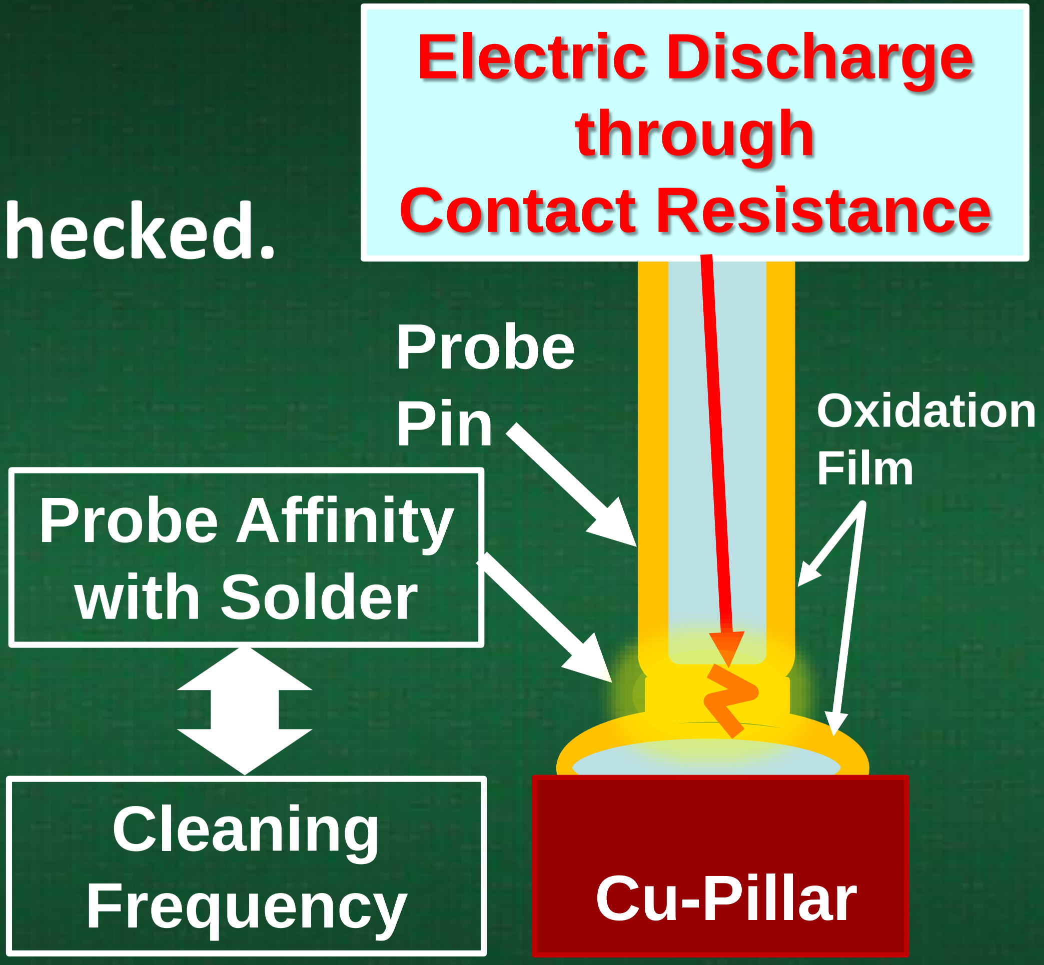



Figure 6-1 Illustration of Solder Capped Cu-Pillar

# 6.1. Test for Wet Property to solder : Solder Rubbing Test

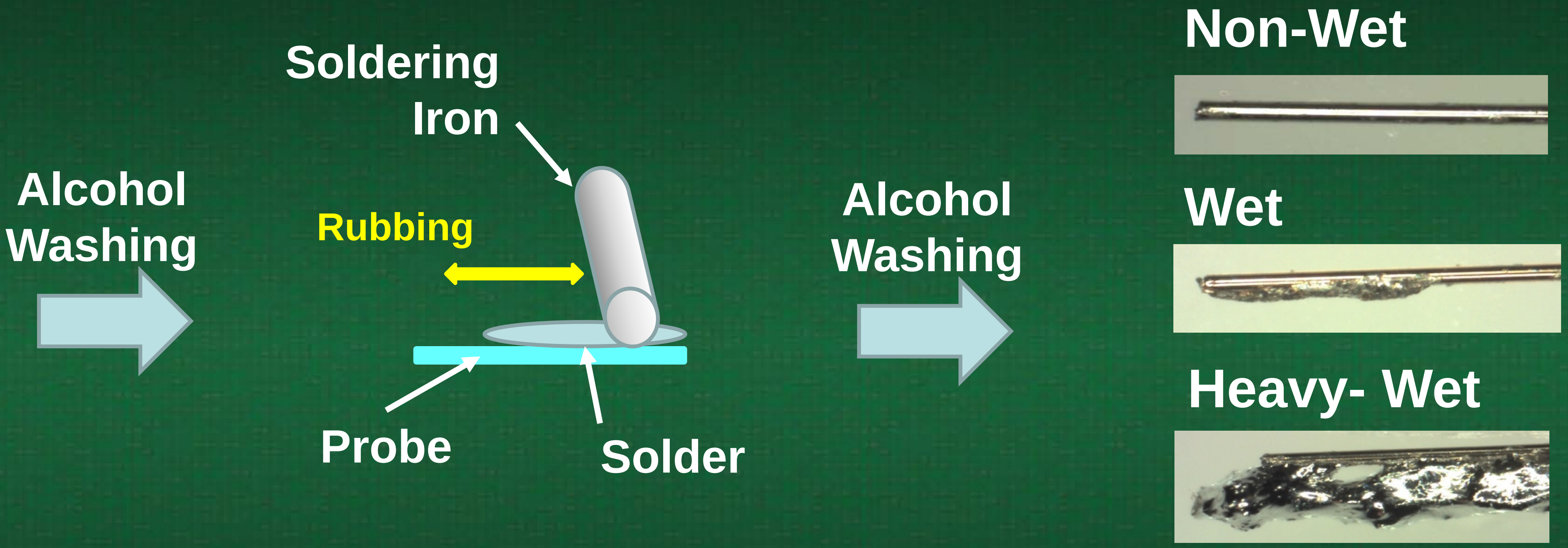
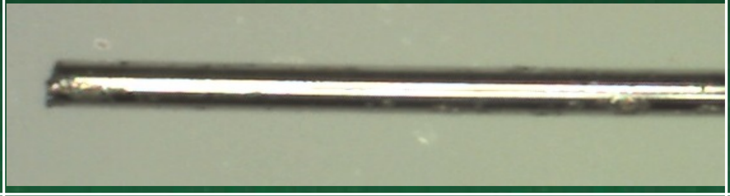
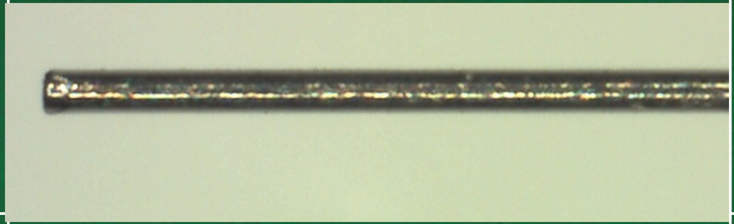
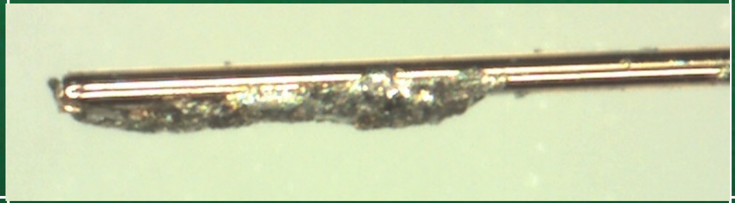
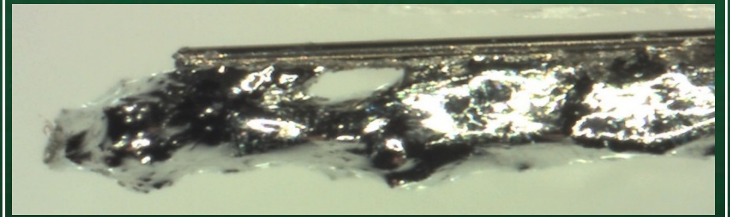



**Figure 6-2 Illustration of Solder Rubbing Test**

Sn/Ag solder of following contents was used :Sn 96.5%, Ag 3.5%

# Table 6-1 Tip Appearance after Solder Rubbing Test

| | Appearance Photo | Property | Comment |
|---|---|---|---|
| Rhodeo6 |  | Non-Wet | |
| Rhenium Tungsten |  | Non-Wet | |
| BeCu |  | Wet | BeCu showed Wet Property. |
| H3C |  | Heavy -Wet | H3C showed Heavy-Wet Property and high affinity with solder due to Silver which is contained both in H3C and solder. Through repeated contacts with solder, oxidized solder debris may easily adhere to probe tip of H3C. |

# 6.2. Electric Discharge Test

This test can be another new CCC evaluation method.

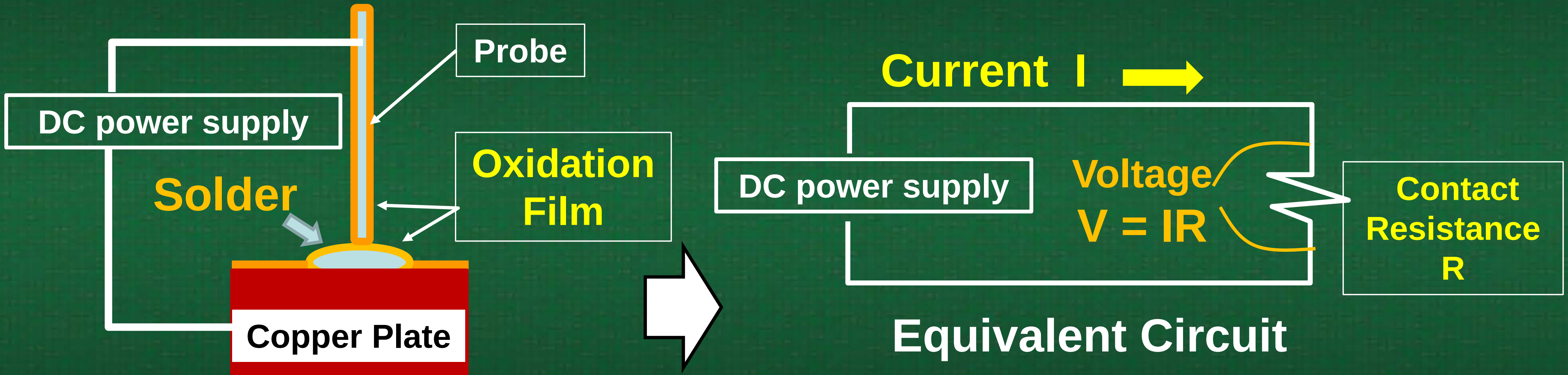



Figure 6-3 Illustration of Electric Discharge Model

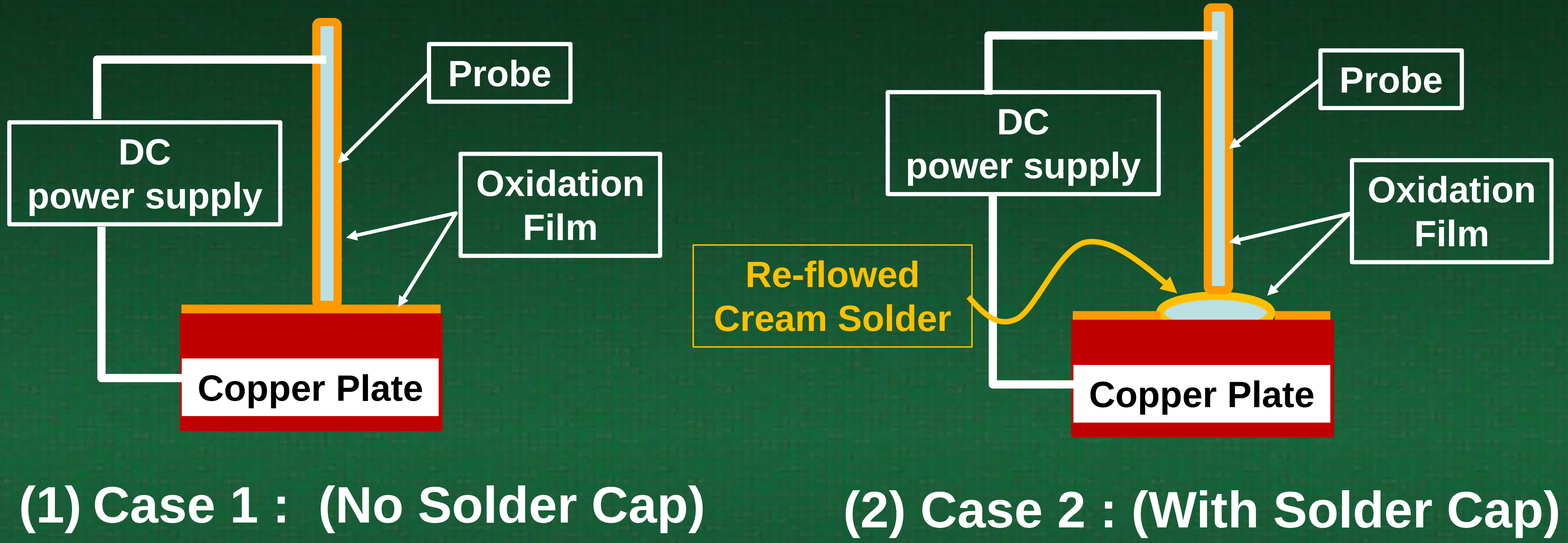



**Figure 6-4  Illustration of Electric Discharge Test**

**Table 6-2  Ingredient of Cream Solder**

| Sn | Ag | Cu | Flux |
|---|---|---|---|
| 84.9 ～ 88.8 % | 2.8 % | 0.3 ～ 0.4 % | 8 ～ 12 % |

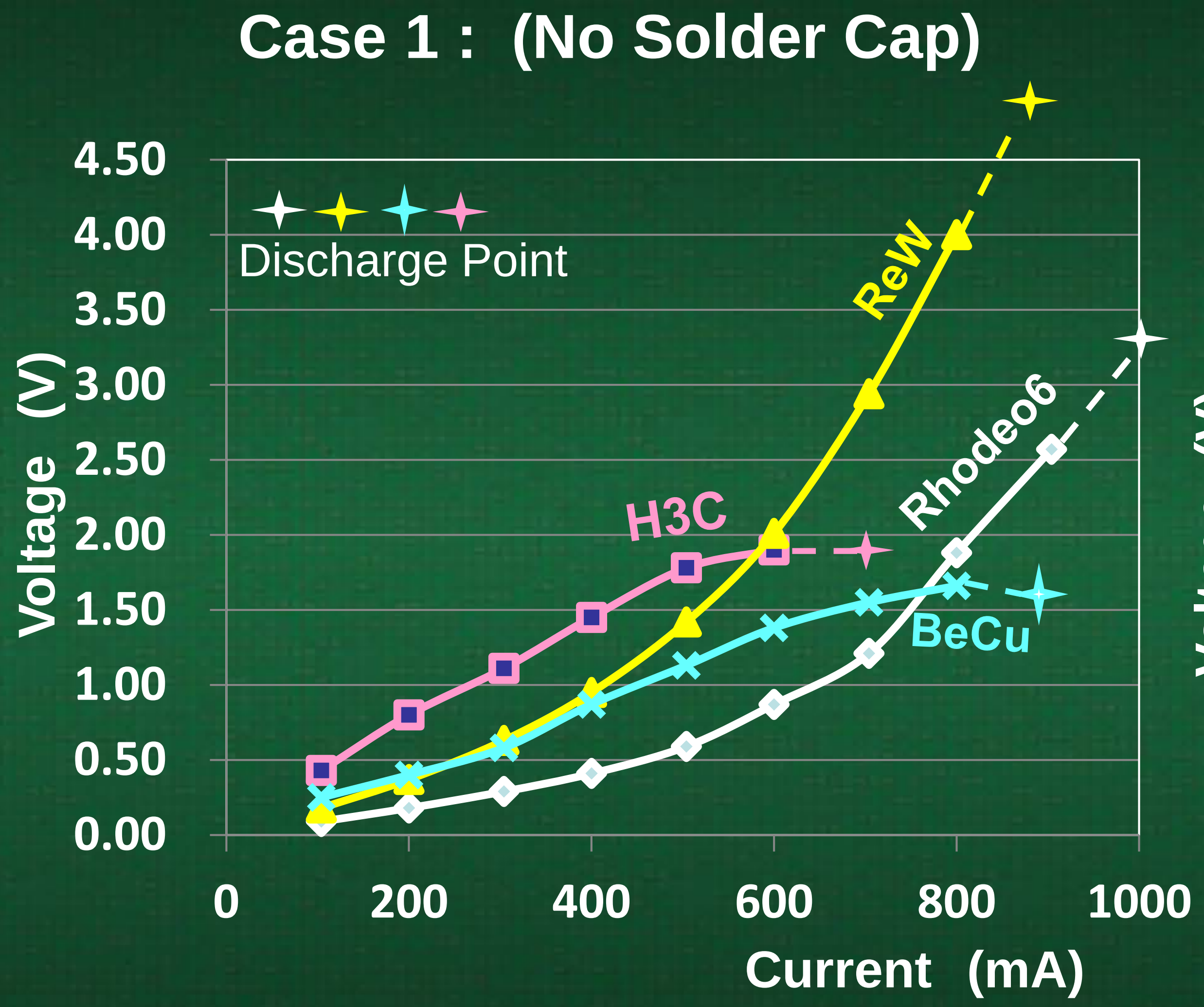
**The contact resistance with solder surface was very high, and it was necessary to shift the tip contact condition to increase contact force enough to break oxidation film on solder surface.**


(1) Case 1 : (No Solder Cap)

(2) Case 2 : (With Solder Cap)

**Figure 6- 5 Tip Contact Condition Shift due to oxidation film on solder**

# Voltage / Current before Discharge



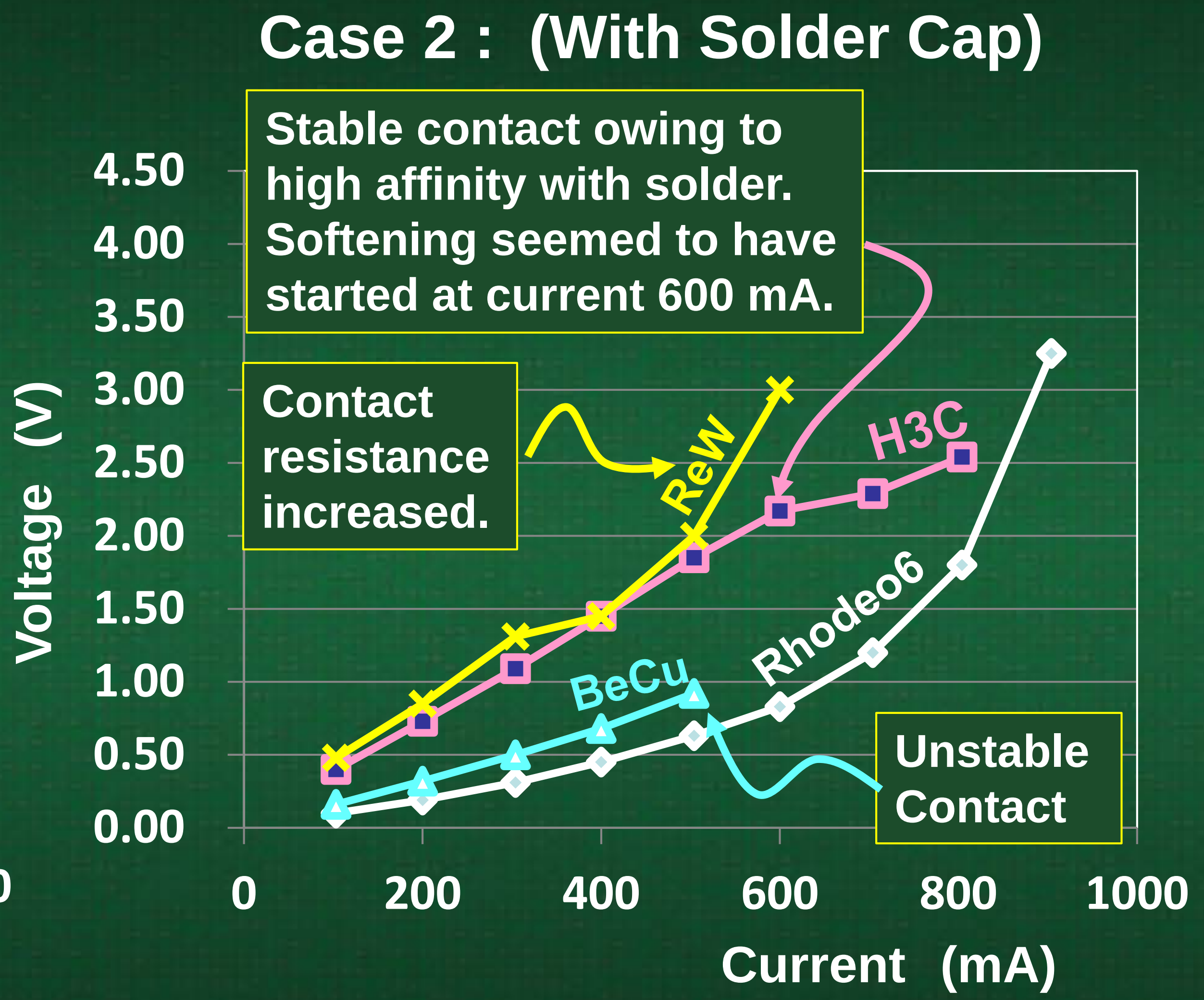
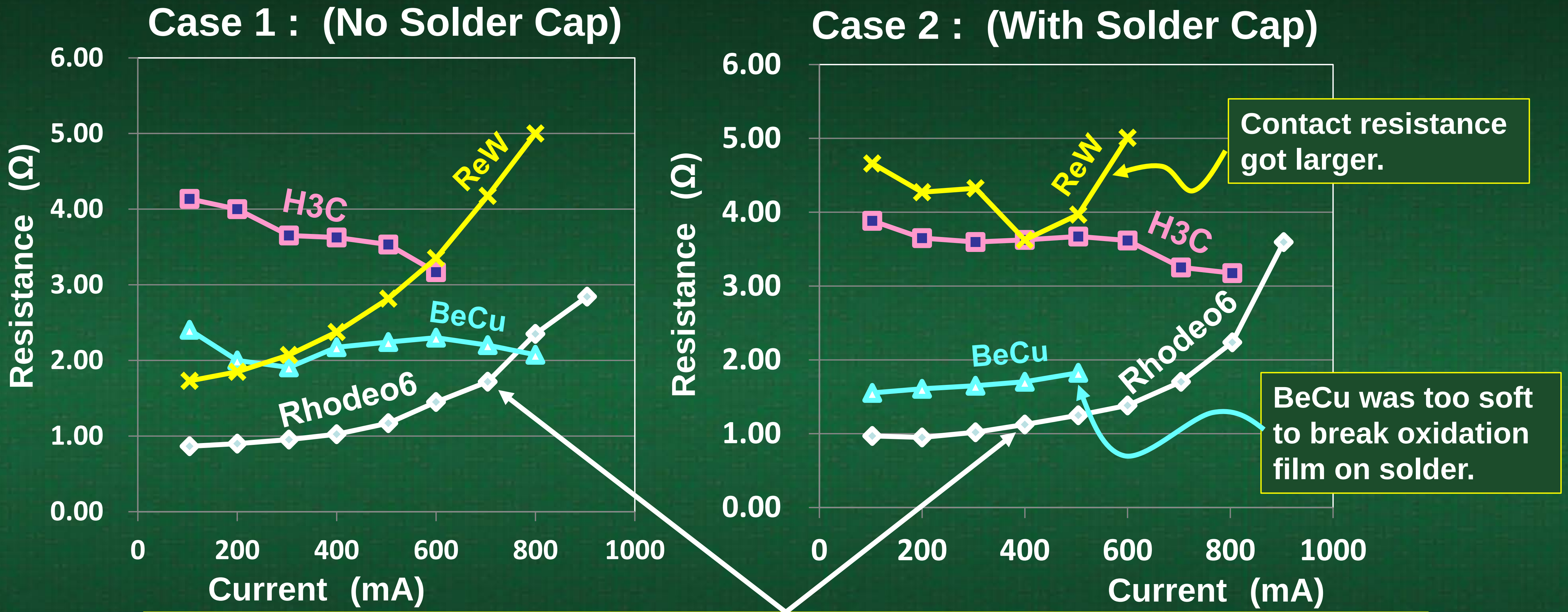




**Figure 6-6 Results of Electric Discharge Test - 1**

# Electric Resistance / Current before Discharge



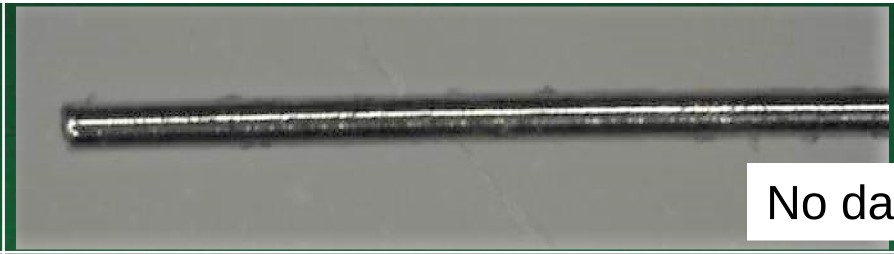
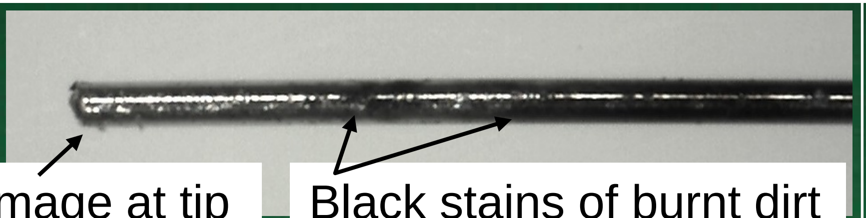
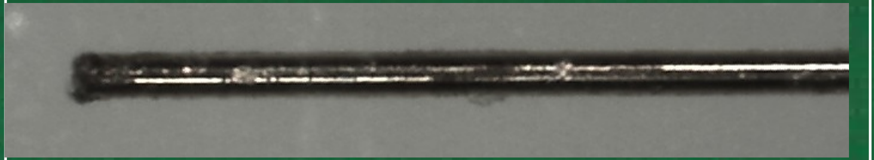
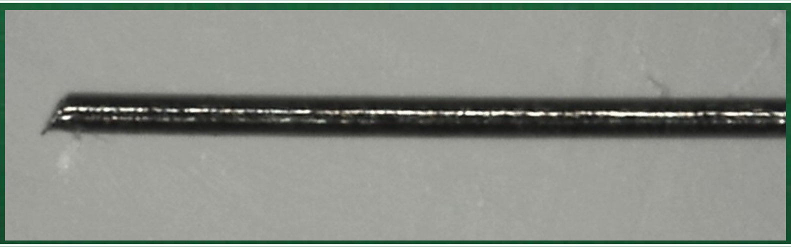
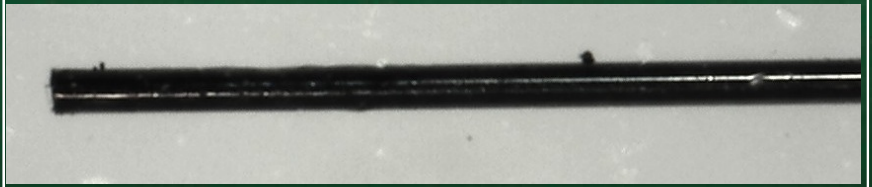

This performance of low resistance will be effective not only for power device but also for inspection of Cu-Pillar in general, including narrow pitch device.

## Figure 6-7 Results of Electric Discharge Test - 2

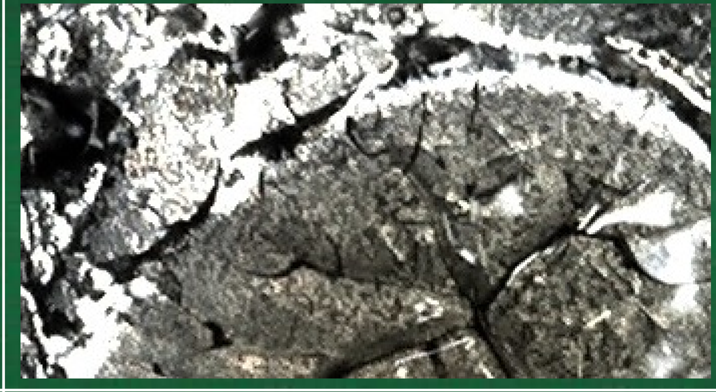
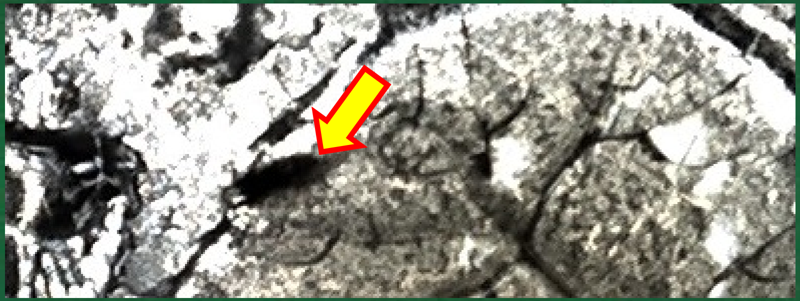
# Table 6-3 Tip Appearance before and after Discharge (Case 1)

| | Before | After Discharge | Damage |
|---|---|---|---|
| Rhodeo6 |  |  | No Damage |
| BeCu |  |  | Oxidized & Color Changed |
| Rhenium Tungsten |  |  | Heavily Oxidized *& Charred* |
| H3C |  |  | Melted & Bent |

# Table 6-4 Tip Appearance before and after Discharge (Case 2)

| | Before | After Discharge | Damage |
|---|---|---|---|
| Rhodeo6 |  |  | No Damage |
| BeCu |  |  | Oxidized at Tip End |
| Rhenium Tungsten |  |  | Heavily Oxidized |
| H3C |  |  | Heavily Oxidized |

# Table 6-5 Solder Surface Appearance before & after Discharge (Case 2)

| | Before | After Discharge | Damage |
|---|---|---|---|
| Rhodeo6, BeCu | No significant difference between before and after discharge. | | No Damage |
| Rhenium Tungsten |  |  | Lack Hole |
| H3C |  |  | Lack Hole |

# 7. Summary

## 7.1. New method to measure CCC of thin wire has been confirmed.

## 7.2. CCC Measurement results by thin foil melting method:

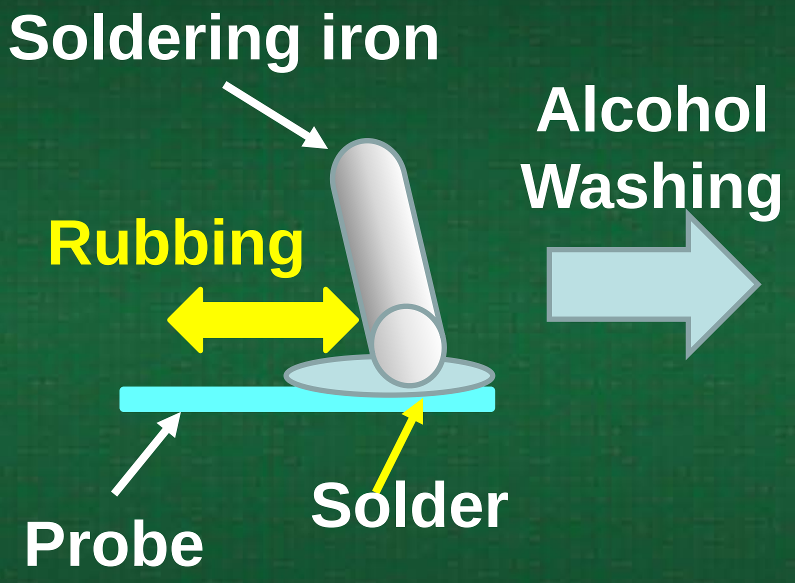
1) Order of CCC
   Rhodeo6 > Beryllium Copper > Rhenium Tungsten > Paliney H3C

2) As current increased, Beryllium Copper and Paliney H3C seemed to have softened, resulting in lower available CCC.

3) Basic Theory of CCC has been verified.

# 7.3. New Discoveries through experiments :

## [1] Test for Wet Property to Solder





- Non-Wet : Rhdeo6

→ Low Cleaning Frequency

- Wet : BeCu

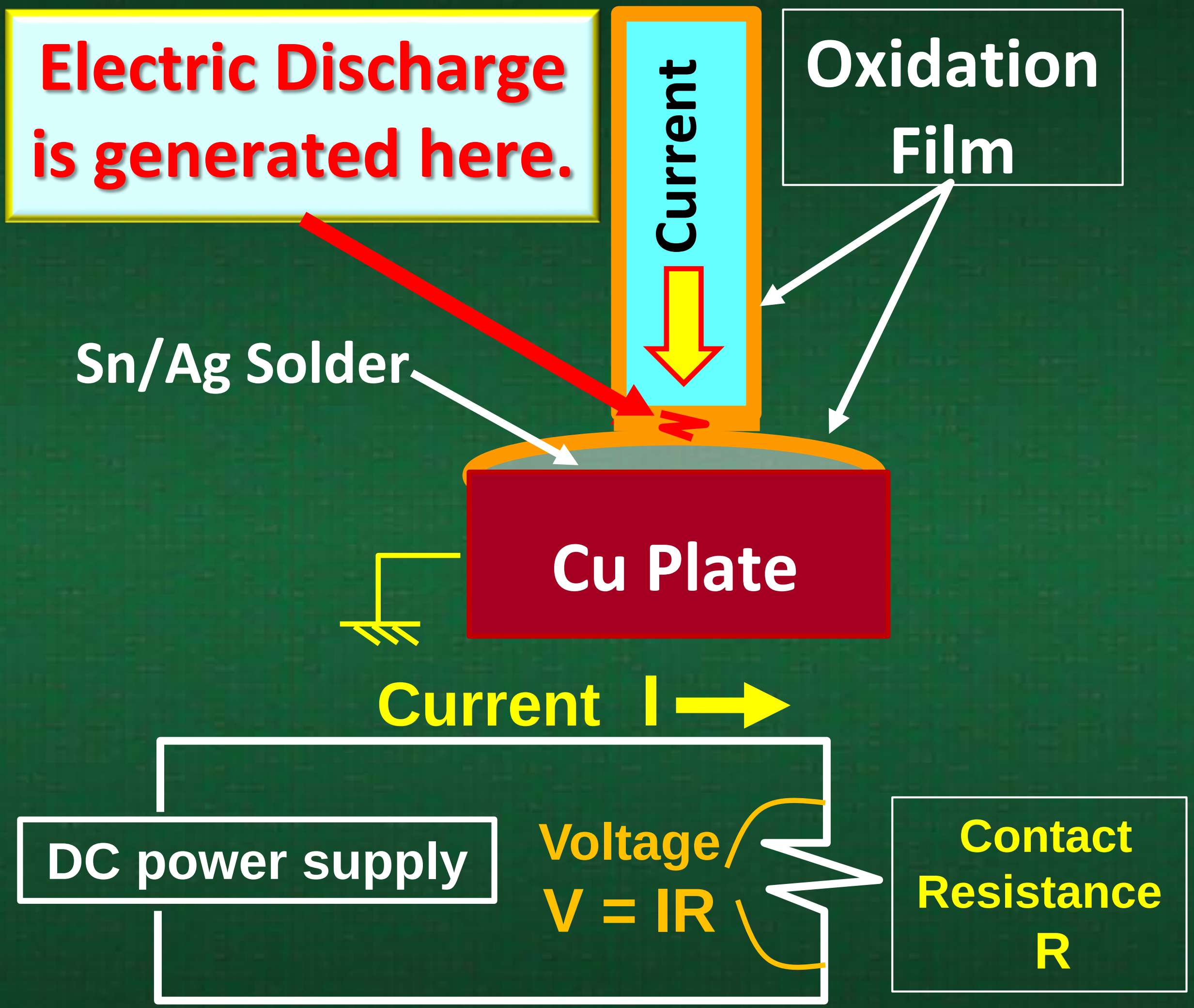
→ High Cleaning Frequency

- Heavy-Wet : H3C

→ Very High Cleaning Frequency

Figure 7-1 Summary for Test of Wet Property to Solder

## [2] Electric Discharge Test




- Electric Discharge is generated through Contact Resistance.
  The larger the Contact Resistance, the larger the Discharge Energy, and the larger the Damage to Probe Tip and Solder Cap.

- Rhodeo6 showed highest current before discharge, showing no damage after discharge.
- Rhodeo6 showed lowest electric resistance, including low contact resistance.

**Figure 7-2 Summary for Electric Discharge Test**

# 7.4. Comparison of CCC Measurement Methods

Table 7-1 Comparison of CCC Measurement Methods

| Method | Judgement Standard | Suitable Object |
|---|---|---|
| ISMI CCC | Force Reduction Rate Depress | Probe |
| 1st New Method Foil melting method | Temperature Difference | Probe Material |
| 2nd New Method Discharge Method | Current Before Electric Discharge | Probe and Probe Material |

# 7.5. Performance Comparison of Probe Materials

## Table 7-2 Performance Comparison between Rhodeo6 and other materials

| Material | Affinity with Solder | Oxidide | Cleaning Frequency | Maximum Current before Softening or Discharge to Solder Cap | Damage on Tip or Solder Cap after Discharge |
| --- | --- | --- | --- | --- | --- |
| Rhodeo6 | Low | No Oxide | Low | 900 mA | No Damage on both Tip and Solder Cap |
| | Non-Abrasive Cleaning Gel is available. | | | | |
| Rhenium Tungsten | Low | Heavily Oxidized | High | 600 mA | Tip Oxidized Lack on Solder |
| BeCu | High | Easily Oxidized | Abrasive Cleaning Gel or Sheet is required. | BeCu : 500 mA | BeCu : Tip Oxidized |
| H3C | Very High | | | H3C : 600 mA | H3C : Tip Oxidized, Lack on Solder |

# 8. Acknowledgement

| | | |
|---|---|---|
| Photo |  |  |
| Name | Mr. Nobuo Iwakuni | Mr. John Sterrett |
| Company | Assisted<br>as a private position | Specialty Coating Systems |
| Location | Hiroshima, Japan | USA |
| Content of assist | Support to the experiment | Great Help in coating<br>for sample development |